

#5

Mass Experiment

Optic Pick Off
and Counter

2.3

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The accuracy with which the point of zero crossing is determined is fundamental to the accuracy of the entire system. Although the frequency fundamental basic measurement is time it is dependent upon the distance resolution of the zero and velocity of the mass at zero crossing crossing detector, as follows:

$$D = VT$$

$$\text{Time Resolution} = \frac{\text{Velocity at zero crossing}^{\text{displacement}}}{\text{Distance Resolution}}$$

Q

Taking a nominal frequency

of 1 c.p.s. & a peak displacement
of 1" will give a peak
velocity of $\frac{dx}{dt} = X 2\pi \cos \theta \omega$

$$= 1 \cdot 2 \cdot 3.14 \cdot 1$$

$$= 6.28 \approx 6 \text{ "/sec.}$$

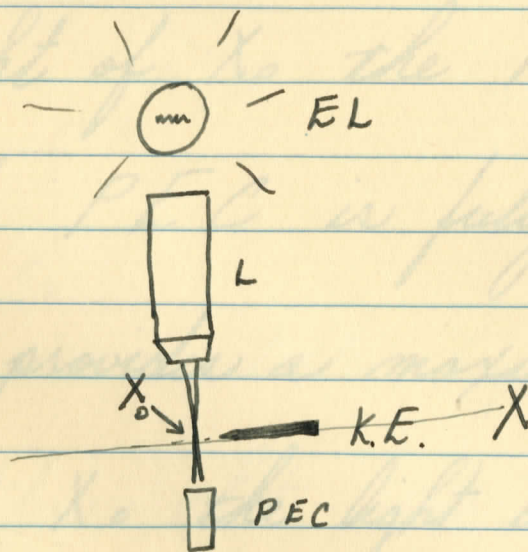
For a time resolution of
5 mSec. the distance resolution
must then be.

$$\text{Dist} = \text{Vel.} \times \text{Time}$$

$$= 6 \text{ "/sec} \times .5 \times 10^{-3} \text{ sec}$$

$$= 3. \times 10^{-3} \text{ "}$$

A fine narrow beam of light interrupted by a ~~thin~~ knife edge has been chosen for the pick-off or zero crossing detection method. This is shown diagrammatically in Fig _____



An incandescent bulb E.L. illuminates a slit in the optic

tube assembly L which is
then focussed as a ^{vertical} ribbon
of light $.001''$ wide at X_0 .

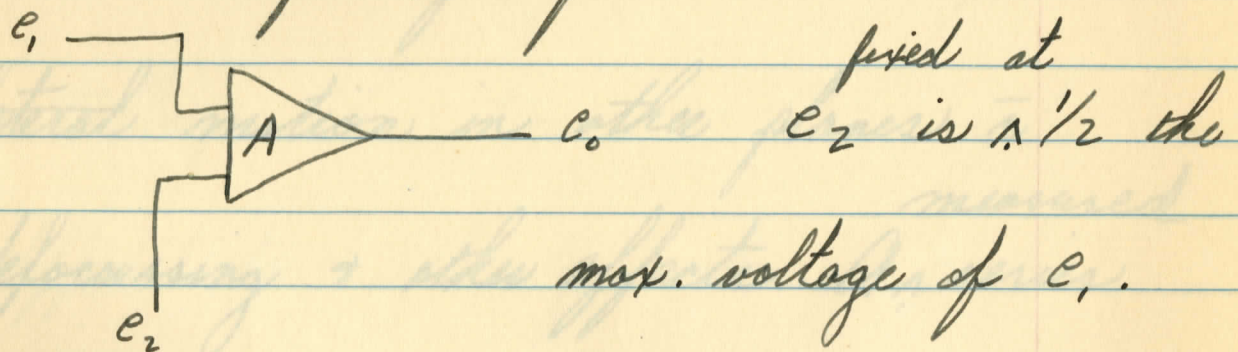
A knife edge K.E. is attached to
the oscillating mass and moves along
the axis X . At all points

right of X_0 the photo electric
cell P.E.C. is fully illuminated and
It provides a maximum light output.

At X_0 the light is cut off in
 $.001''$ and remains off when
the mass is left of this point.

The system has then an inherent accuracy of $0.001''$. This is further enhanced by the electronic circuitry as follows.

The voltage e_1 rep^{res} is the output of the photocell while ~~is~~ fixed at



A is a stable high gain differential amplifier that will provide an output of $\sim 20V$ for a $1mV$ difference between e_1 and e_2 .

The slope of the PEC output is several volts / 10^{-3} inches as the light ^{mass knife} crosses the light beam. This results in a theoretical resolution of micro-inches. Since there Practically there is some lateral motion in other planes & defocussing + other effects. A ^{measured} series of curves & controlled errors introduced are given in fig. and show that a resolution of 10^{-4}

inches may be reasonably expected.
This is more than an order of
magnitude greater than the required
resolution.

2.4 The ^{zero crossing} output of the detector
must then be converted to signals
controlling the timer. A simple
differentiator will generate a pulse
each time zero is ~~gross~~ crossed.
Since zero is crossed 2x each
cycle & from alternately opposite

directions, only ~~those~~ pulses of a single polarity will be passed to the counter which will then count every other complete cycle.

This arrangement will be used only in the testing phases for investigative purposes. ~~It~~ The actual arrangement ~~used~~ which will be used during mass measurement will consist of counting a number of timing a fixed number of

cycles. Within the limits imposed the greater the number of counts cycles counted the greater the accuracy, assuming random errors. The time accumulated will be a direct function of the number of counts while the random errors will accumulate as the square root of the signal. The signal to ~~noise~~^{error} ratio ~~ten~~ ~~signal to error~~) will then increase as the square root of the number of cycles taken. For example if random errors existed in the

time measurement such that
the individual time cycle resolution
were only 1 m sec. by
counting over 4 cycles this could be
reduced to the required $\frac{1}{2}$ m sec.
resolution. The timer used in
the experiment will an ordinary
H.P. $\bar{e}$ a ^{max.} time resolution of
 $\approx 10^{-6}$ sec. Overall system time
resolution should be $\leq 5 \times 10^{-5}$ sec.

2.5 A system for zero disp
initial displacement should present
no great problem - The ^{magnitude of} initial
displacement will be a compromise among
several factors including distance resolution
available, working distance of springs,
space available and bearing size -
A nominal distance of 1" ^{total max. displacement} has been
chosen here. Since the bearing used
will ~~be~~ allow only rectilinear motion
~~only~~ some form of simple stop at
 ~ 0.5 " max. deflection & a positive

manual
release is needed. ~~This will be~~
~~manual -~~

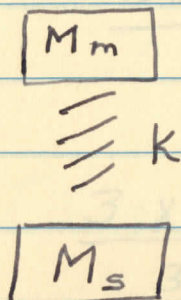
Essentially
2.6 Frictionless support is
limited to a few choices here
of which the most obvious is an
air bearing. A quick and dirty
approximation of such a bearing is
a block of dry ice supporting a
smooth surface. ~~Here~~ Such makeshift
is not justified here and a ~~ss~~
simple linear bearing $\bar{c}$ lateral γ

bottom surfaces will be used.

Such a bearing ~~to~~ may for our purposes be considered frictionless - In
+ low volume
air supply of a few P.S.I. will
be required for operation -

Other considerations: In flight
The
finite mass of the space ship is
~~finite as compared to earth~~
cannot be neglected as may the earth's
mass in the ground situation - This
limited ~~to~~ mass results in some
~~so~~ a small amplitude of oscillation

which will shift the frequency of oscillation as follows.



M_m = Mass to be measured

M_s = Mass of Ship

K = Spring Constant

$$F = \frac{1}{2\pi} \sqrt{\frac{K(M_m + M_s)}{M_m M_s}}$$

This has the practical effect of an ^{apparent} equivalent mass, $M_E = \frac{M_m M_s}{M_m + M_s}$.

Spring values of

$$M_m = \frac{150}{9} \text{ pounds}$$

$$M_s = \frac{30,000}{9} \text{ pounds}$$

$$\frac{3 \times 10^4 \times 1.5 \times 10^2}{3.0150 \times 10^4} = \frac{4.5 \times 10^6}{3.015 \times 10^4}$$

$$= 149.254 \text{ \#}$$

In absolute terms the weight
would be "short" by $\sim .75$ pounds.

This error ^{with} ^{essentially} should remain constant

3 large variations in the ships mass
calculated or
and may be calibrated by
a single on-station measurement

$\bar{c}$ a known mass.

The first phase of the demonstration will consist of assembling the components and testing the validity of the derived calculations including the resolution, accuracy and stability of the proposed instrument using fixed masses. A

2^o phase will consist of construction of a ~~man~~ carrying version and development and test of the features peculiar to this application.

If successful a 3rd phase should be considered which consists of flying the two devices in cylindrical bearings to determine their behavior under weightlessness and to gain operational experience in this principal.

Information and guidance should be during at all phases to the contractor, provided as soon as ^{valid} ~~seen~~ results are obtained.